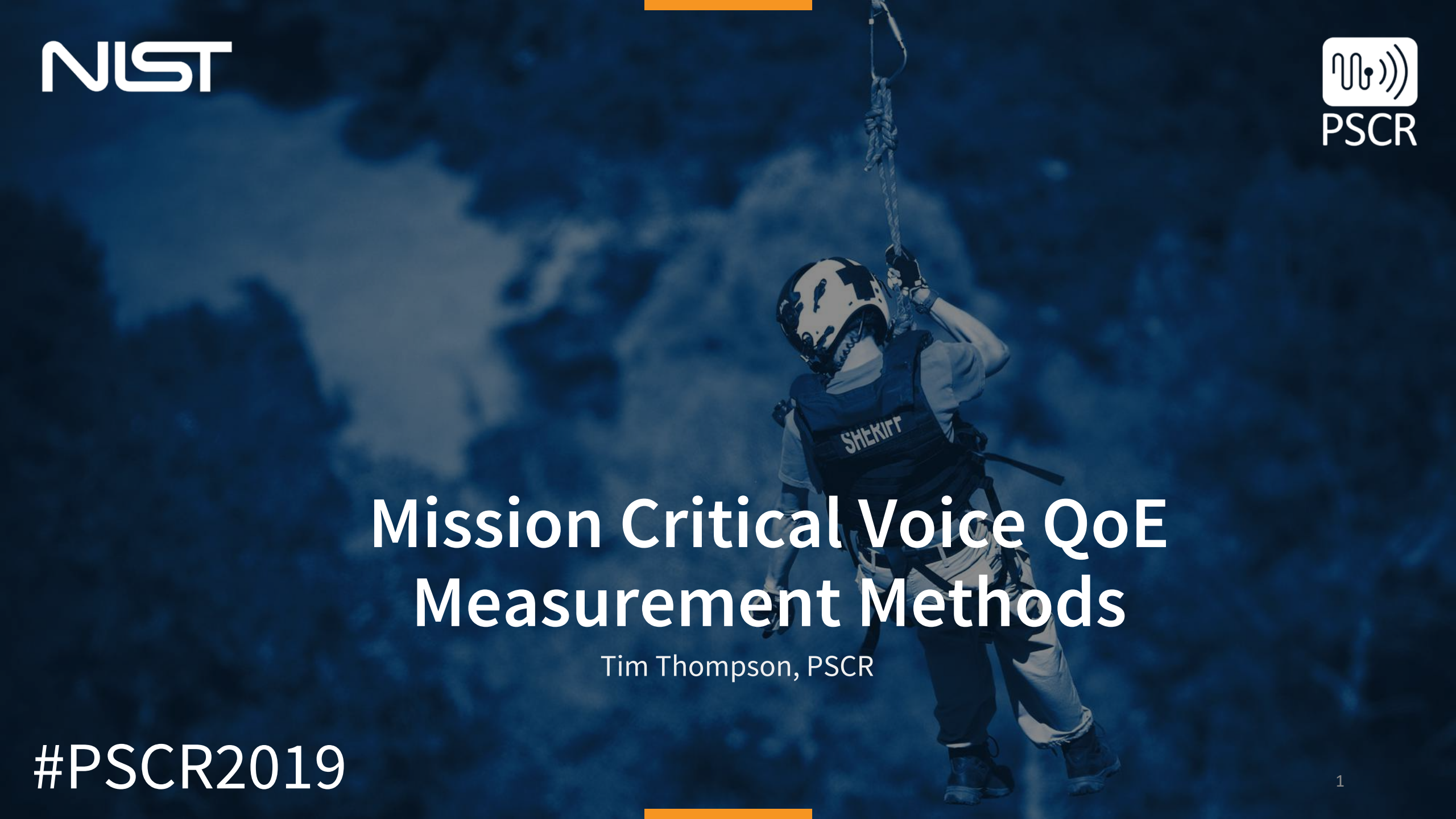


Mission Critical Voice QoE Measurement Methods

Tim Thompson, PSCR

#PSCR2019

DISCLAIMER

Certain commercial entities, equipment, or materials may be identified in this document in order to describe an experimental procedure or concept adequately.

Such identification is not intended to imply recommendation or endorsement by the National Institute of Standards and Technology, nor is it intended to imply that the entities, materials, or equipment are necessarily the best available for the purpose.

*Please note, unless mentioned in reference to a NIST Publication, all information and data presented is preliminary/in-progress and subject to change

Mission Critical Voice QoE Measurement Methods

- First Mission Critical Voice (MCV) Quality of Experience (QoE) Measurement Method Project
  - Mouth-to-Ear (M2E) Latency
- Most Recent MCV QoE Measurement Method Project
  - End-to-End Access Time
- Future Work/Direction
  - Audio Quality/Intelligibility
  - Access/Retention Probability

Existing LMR/LTE Key Performance Indicators (KPI)

- Quality of Service (QoS) and Compliance Based
- Technology Specific
- Depend on Complicated/Proprietary/Internal Measurements
- Example: Push To Talk (PTT) Access Time - Standards
  - TIA Definition: Time Between Button Press and Traffic Channel Transmit
  - 3GPP Definition: Time Between Button Press and Acknowledgement from System (KPI 1)
- QoE Definition
  - Time Between Button Press and Receiving User Hearing Intelligible Transmitting User (End-to-End Access Time)

The User Experience: PTT Communications

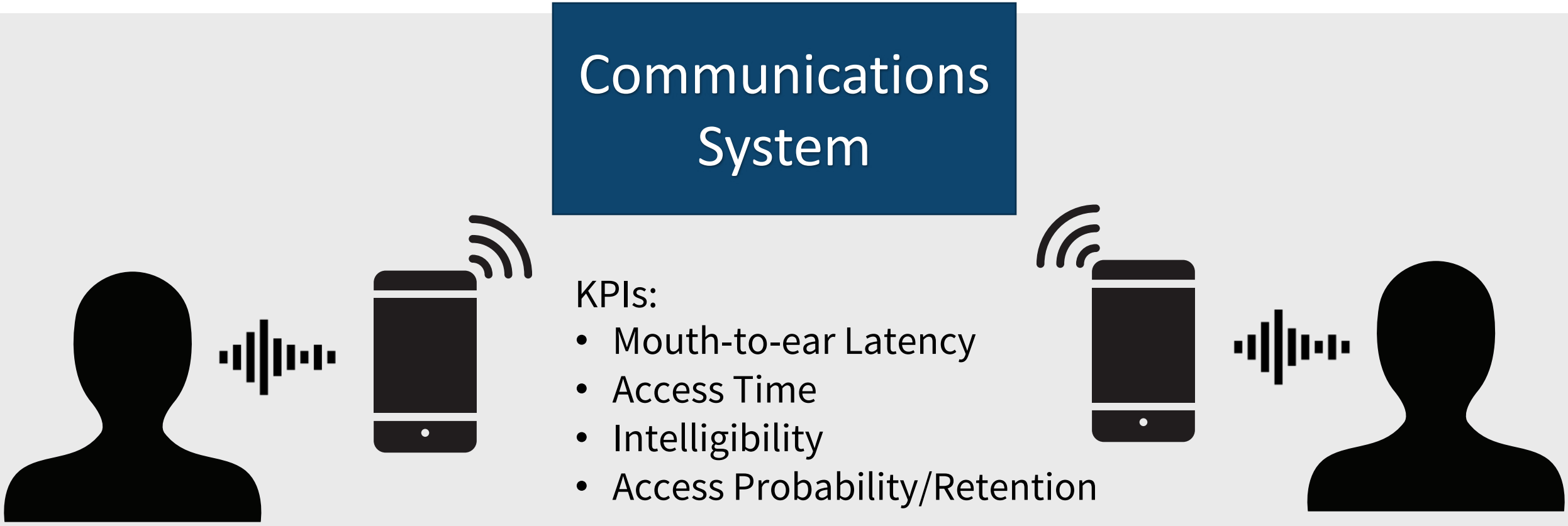
- Press PTT and speak into a device
- Listening to speech output from a device
- It's all about speech

- **Goal - Create an access time measurement system that is:**
  - Based upon the user experience -- speech
  - Comparable and fair across technologies
- **This is not:**
  - Diagnosing internal components of specific systems

QoE KPIs for MCV - MCV Roundtable 2017

- Mouth-to-Ear (M2E) Latency
  - Time it Takes Audio to Get from Transmitting User to Receiving User
- End-to-End Access Time
  - Time Between Button Press and Receiving User Hearing Voice
  - M2E Latency + Access Delay
- Audio Quality/Intelligibility
  - Public Safety Cares Most About Intelligibility
- Access/Retention Probability
  - Ability to Establish Call
  - Ability to Retain Call

Technology Agnostic Measurements

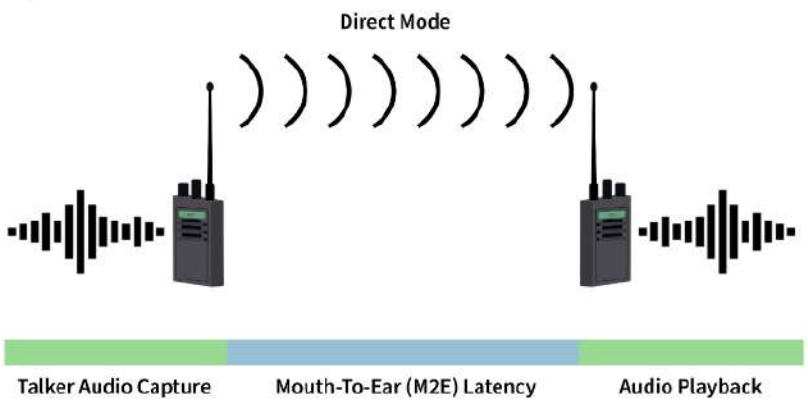


KPIs:

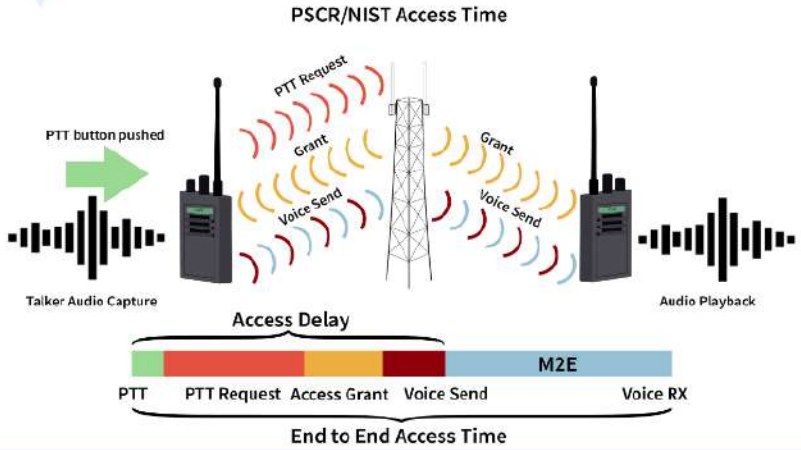
- Mouth-to-ear Latency
- Access Time
- Intelligibility
- Access Probability/Retention

QoE KPIs for MCV

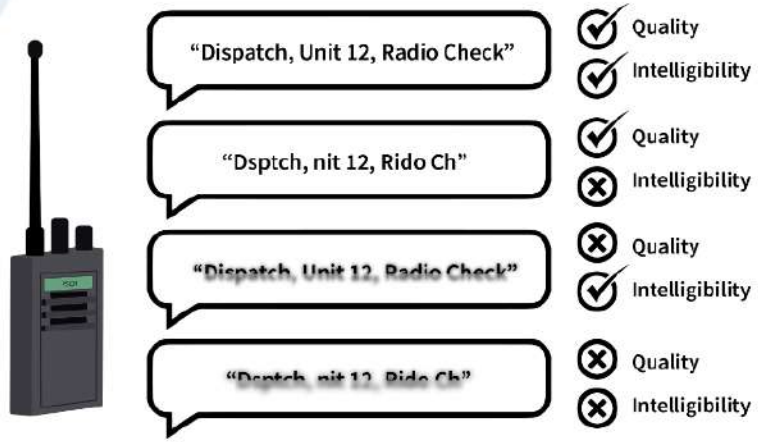
MOUTH TO EAR LATENCY



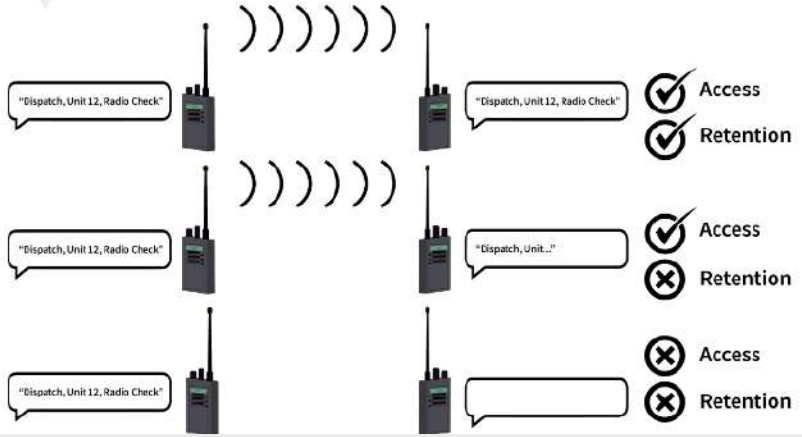
END TO END ACCESS TIME



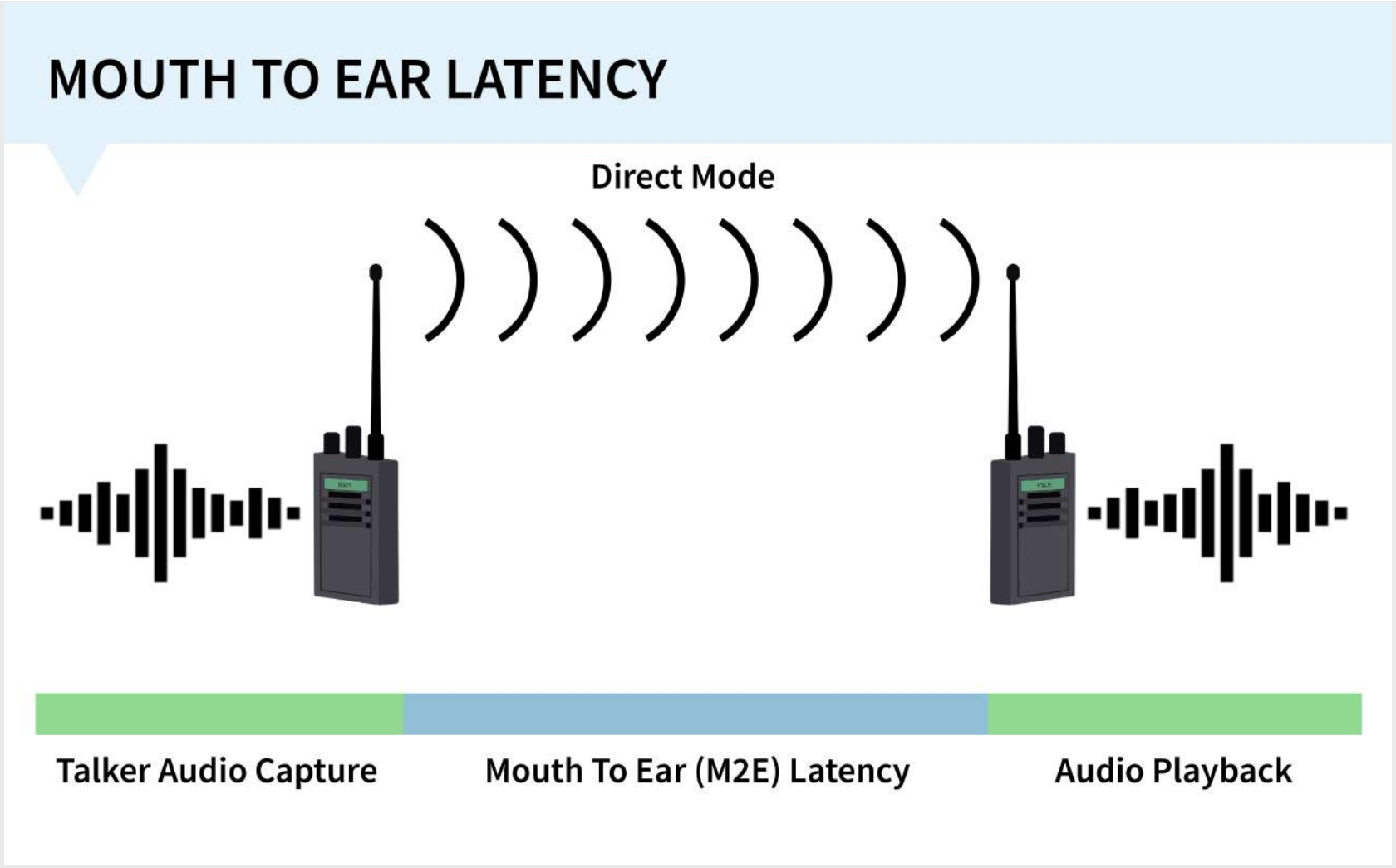
VOICE QUALITY & INTELLIGIBILITY



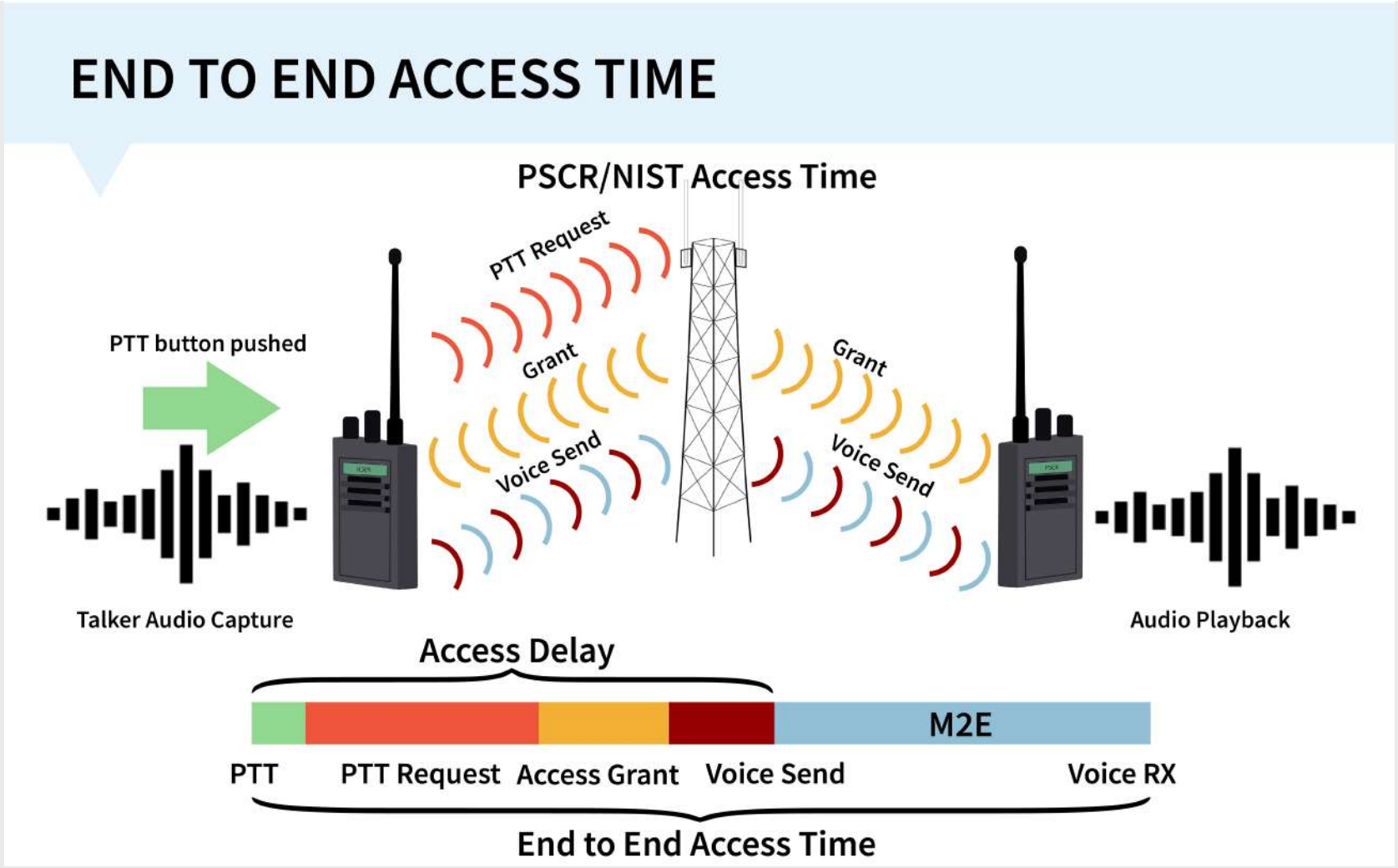
PROBABILITY OF ACCESS & RETENTION



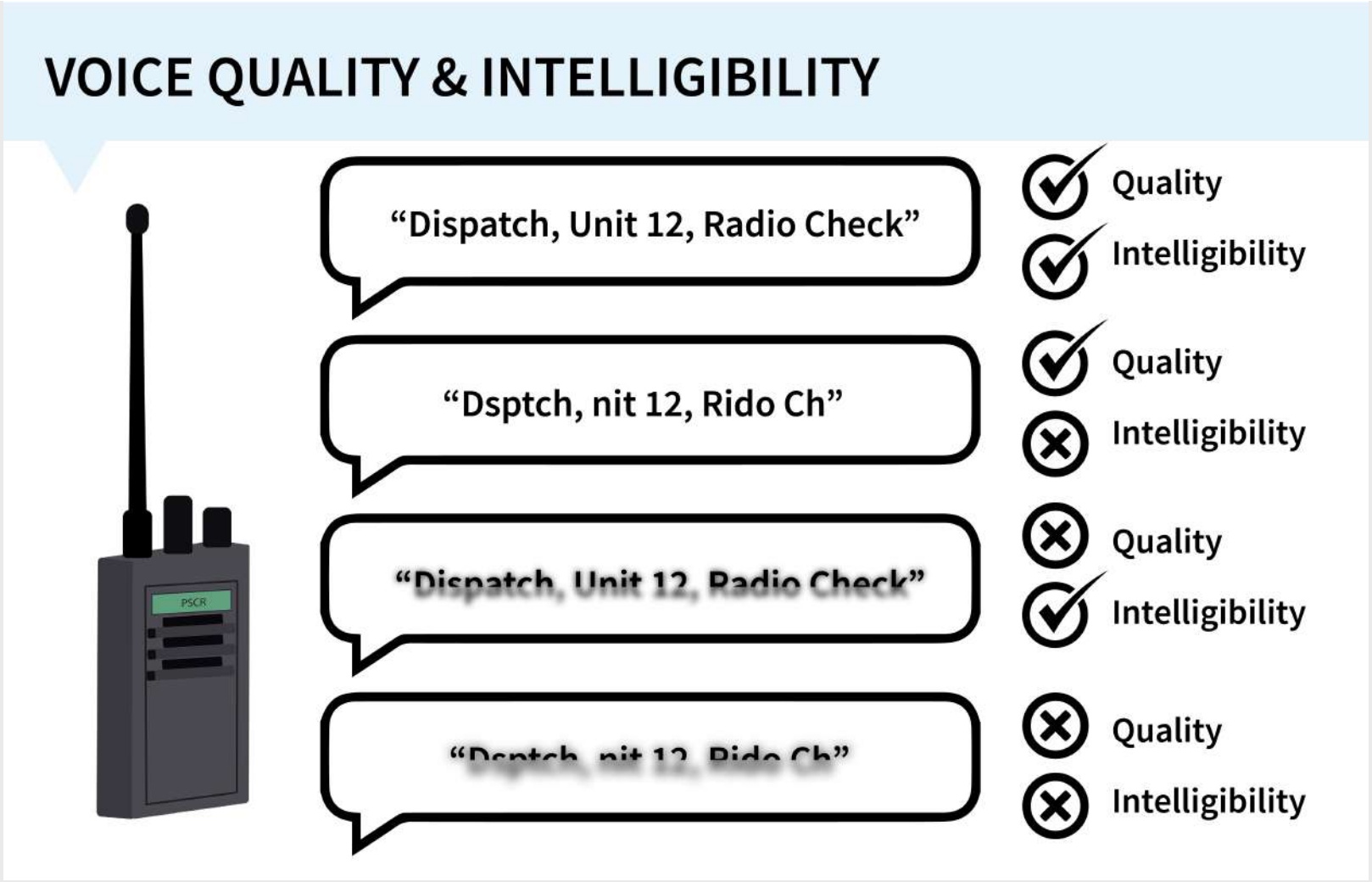
QoE KPIs for MCV



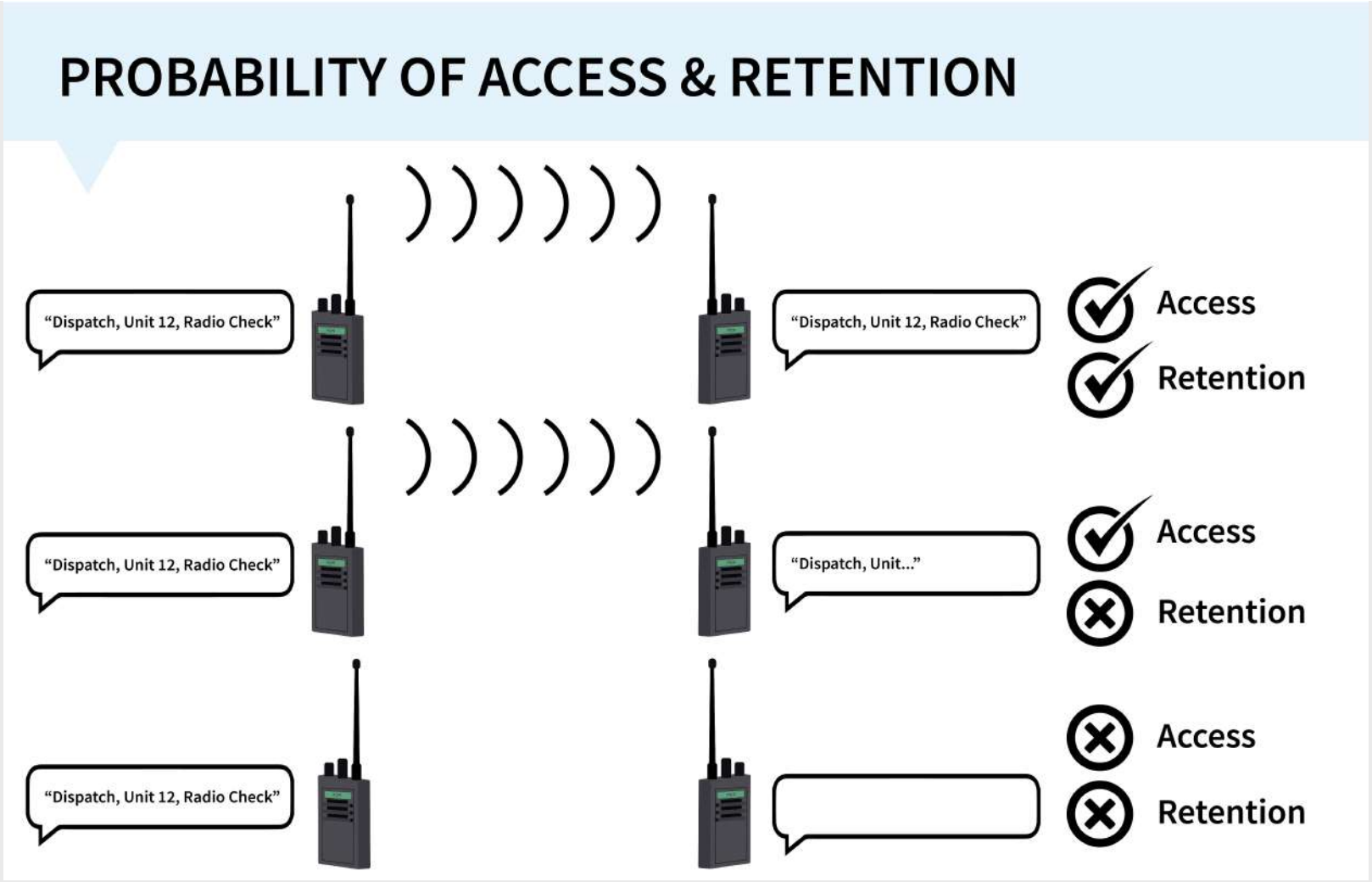
QoE KPIs for MCV



QoE KPIs for MCV



QoE KPIs for MCV

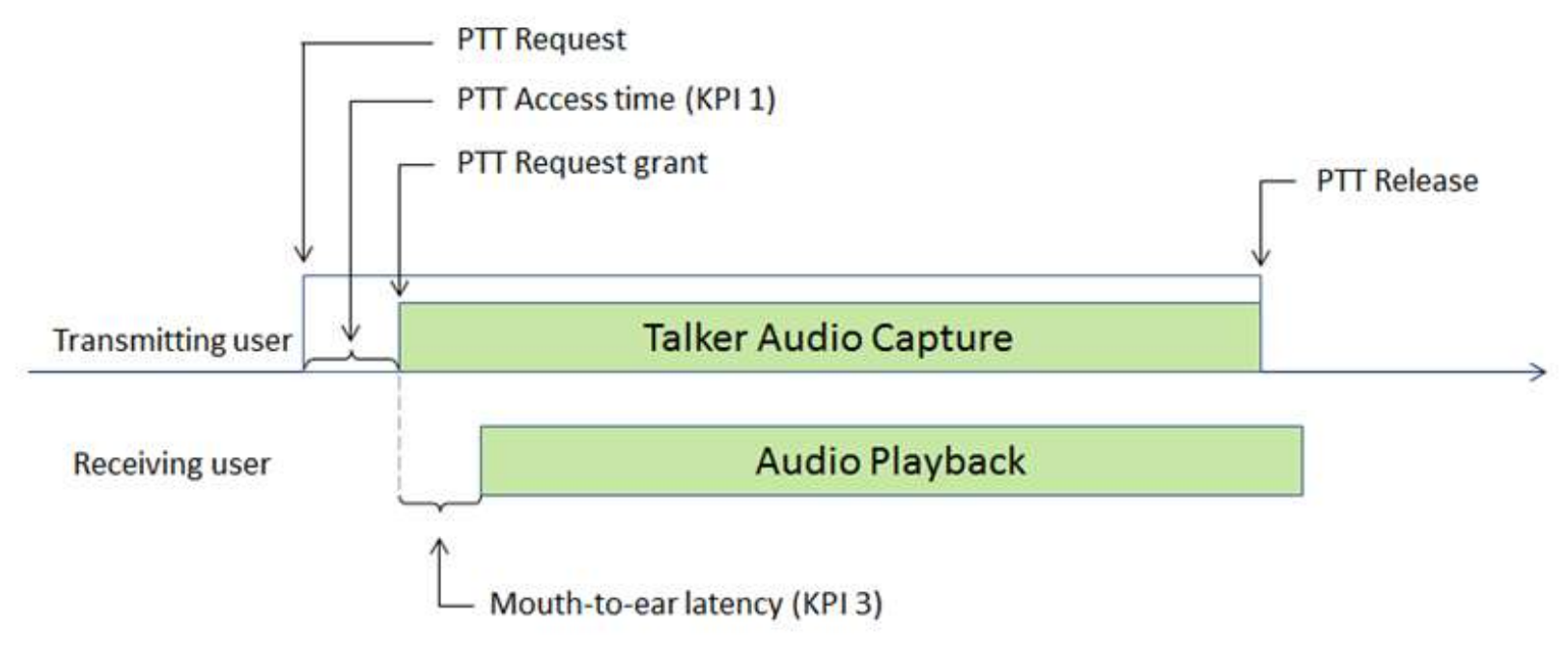


QoE KPIs for MCV - M2E Latency

- M2E Latency Measurement Method
  - Develop a method to measure & quantify M2E latency of any voice communications system
  - Method is based on audio in/audio out and is technology agnostic
  - Very challenging to develop this measurement methodology
    - Development of audio based measurements
    - Optimal volume levels
    - Component to system level testing complexities with uncertainties
  - First step in establishing QoE-based KPIs

3GPP Defined KPIs

- 3GPP M2E Latency and Access Time



3GPP (2017) Mission Critical Push to Talk (MCPTT). 3rd Generation Partnership Project (3GPP), Technical Specification (TS) 22.179. Version 16.0.0 URL: https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=623

M2E Latency Measurement Results

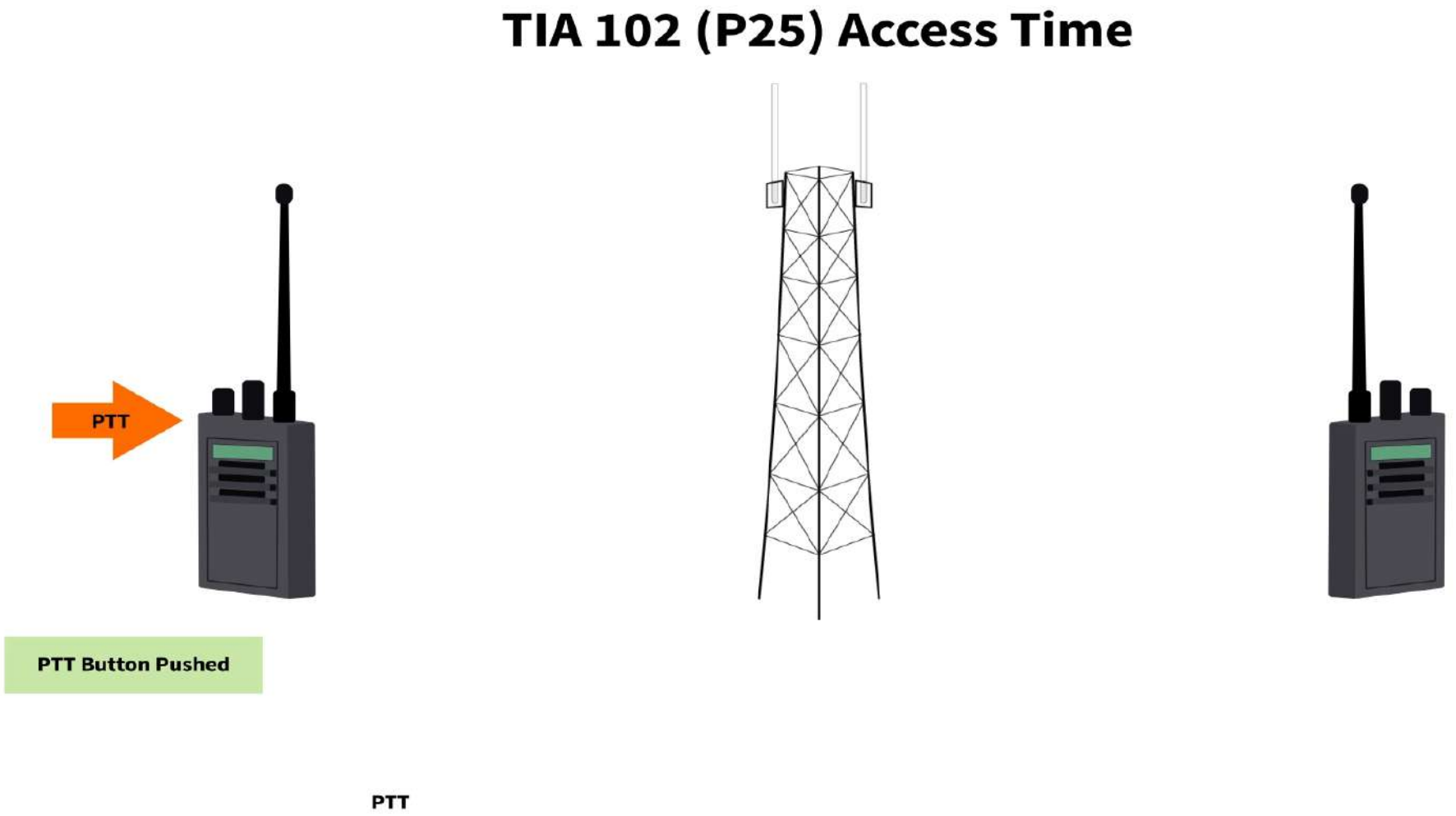
	Single Location Lab (ms)	Two Location Lab (ms)	Two Location Field (ms)
Audio Device Characterization	21.85 ± 0.07	21.85 ± 0.07	21.85 ± 0.07
UHF-P25 Direct	201.4 ± 0.4	201.2 ± 0.3	201.8 ± 0.4
UHF-P25 Trunked	415.8 ± 2.8	413.1 ± 3.3	417.0 ± 2.9
VHF-P25 Direct	201.7 ± 0.5	201.6 ± 0.4	202.4 ± 0.4
VHF-P25 Trunked	403.9 ± 1.8	403.3 ± 2.8	405.3 ± 1.2

- 7 km distance between TX and RX radios for two location field tests
  - 23 µs (microsecond) propagation delay (negligible)
- Untuned prototype Mission Critical PTT system - one location field measurements
  - Not optimized for performance, tested to verify measurement method works on LTE

QoE KPIs for MCV – Access Time

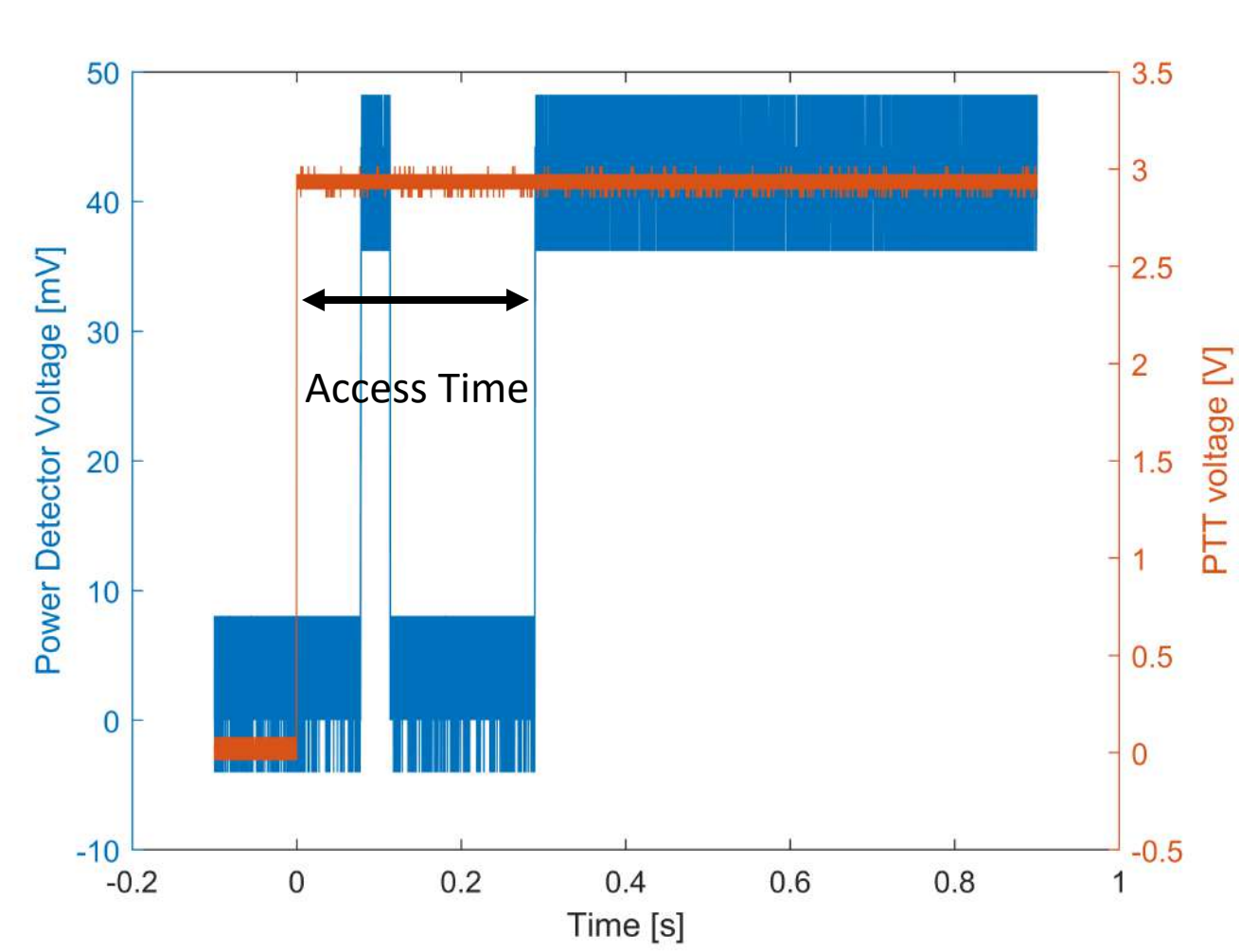
- Access Time
  - Trunked Mode/Mission Critical PTT
  - Direct Mode
  - Measurement Methods/Definitions
    - TIA-102 P25 - Voice Access Time
    - 3GPP Definition - PTT Access Time (KPI 1)
    - NIST/PSCR Definition
      - End-to-End Access Time
  - Very challenging to develop this measurement methodology
    - Tried Several Different Audio Clips
    - Some Words More Challenging than Others to Achieve Intelligibility
  - Critical Next Step in establishing QoE-based KPIs

TIA-102 P25 Access Time – Trunked Mode



TIA-102 P25 Access Time

- A power detector and directional coupler are used to measure the power coming from the TX radio
- TIA-102 defines access time as the time between the PTT signal and the last rising edge of the power detector
- Only works for P25 systems
- The TX radio will transmit an Inbound Signaling Packet (ISP) on the control channel to request the channel
- Once access is granted, the TX radio transmits the encoded audio
- Does not consider the end user

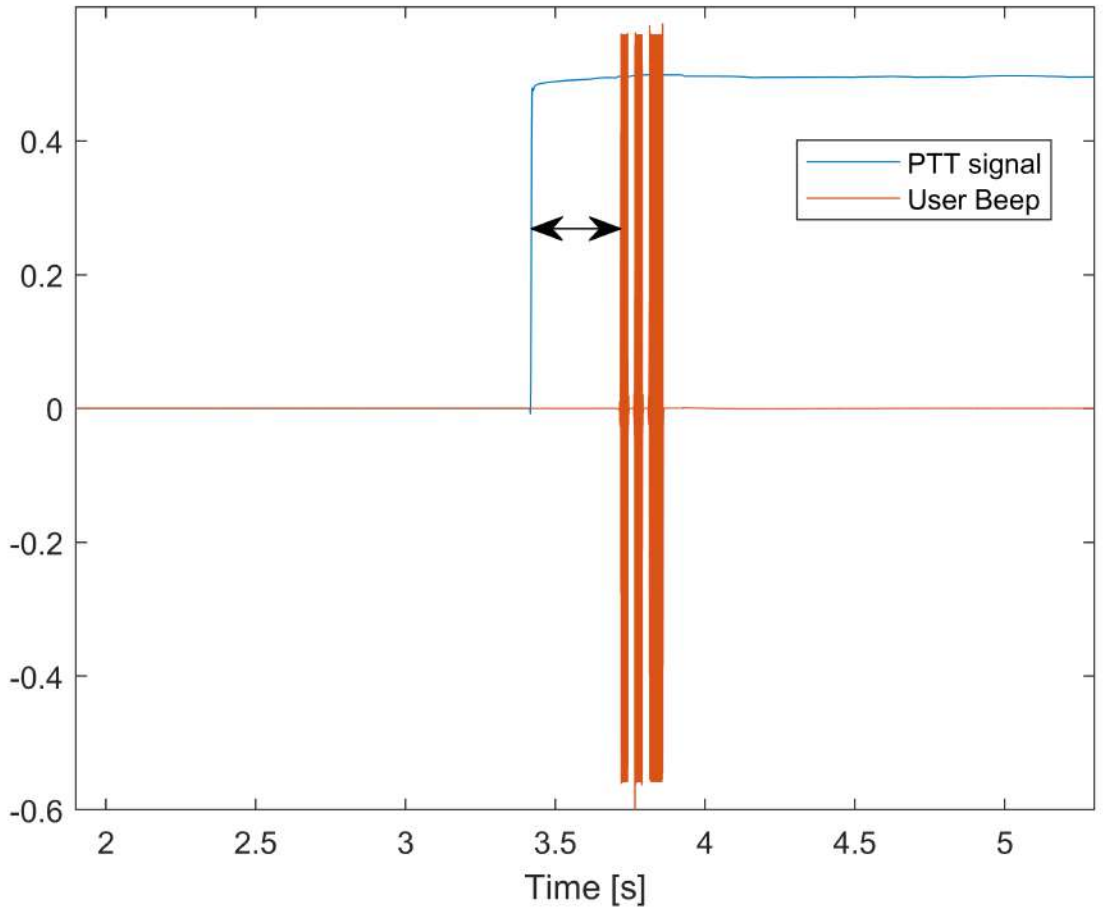


3GPP Access Time

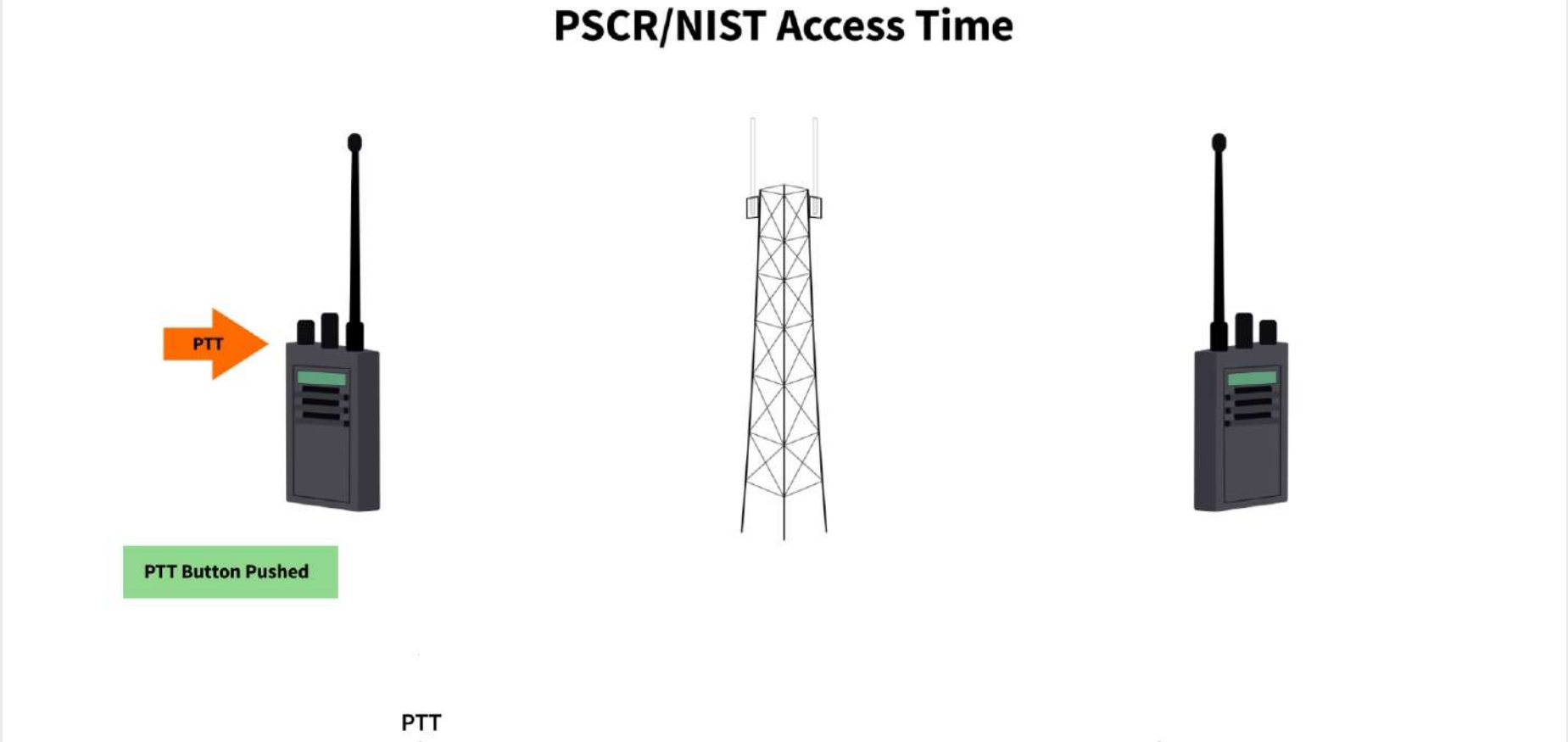
3GPP Access Time

3GPP Defined PTT User Access Time (KPI 1)

- Measures the time between the PTT signal and the signal (or beep) from the TX radio
- Does not consider the end user

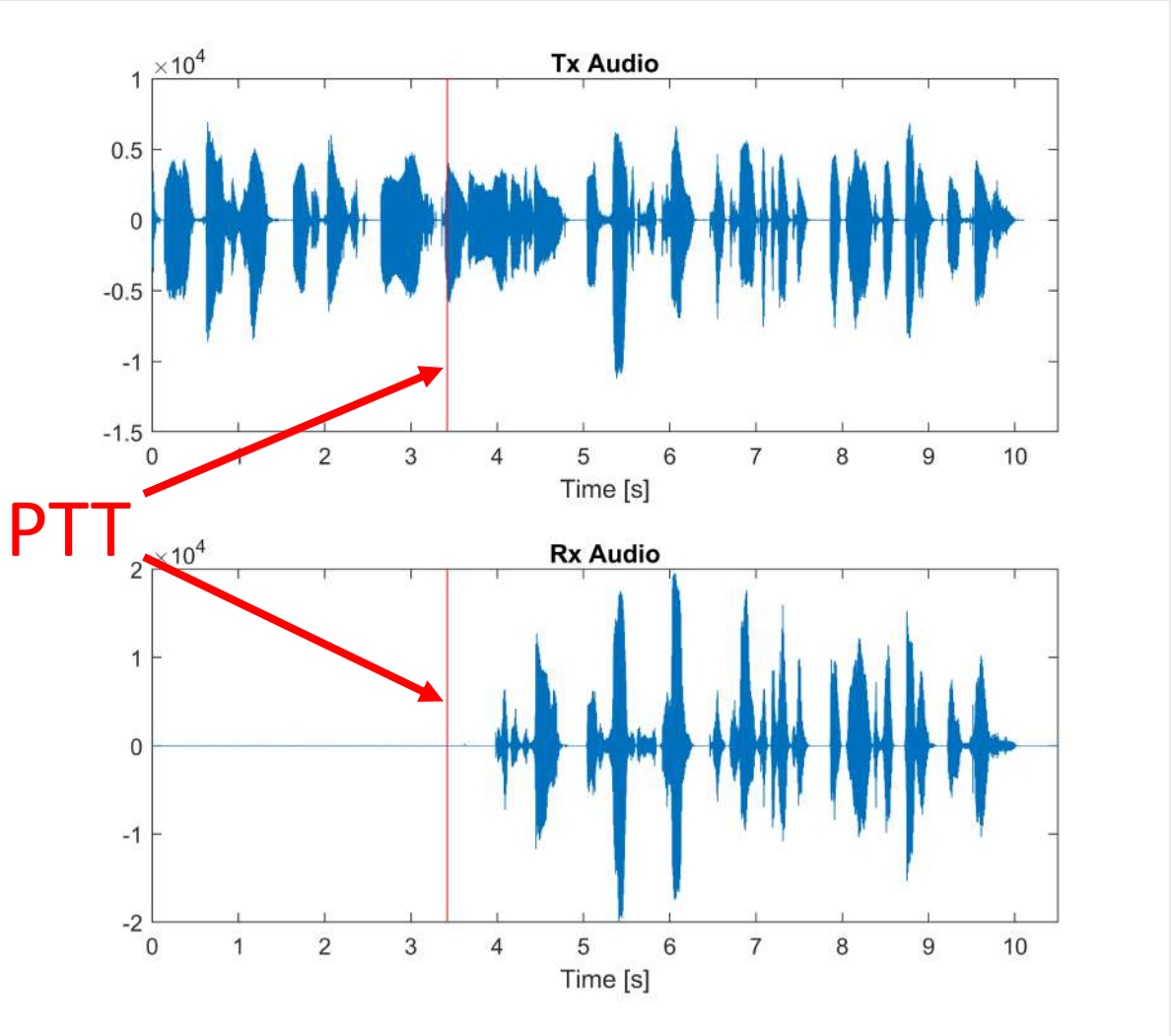


PSCR/NIST End-to-End Access Time



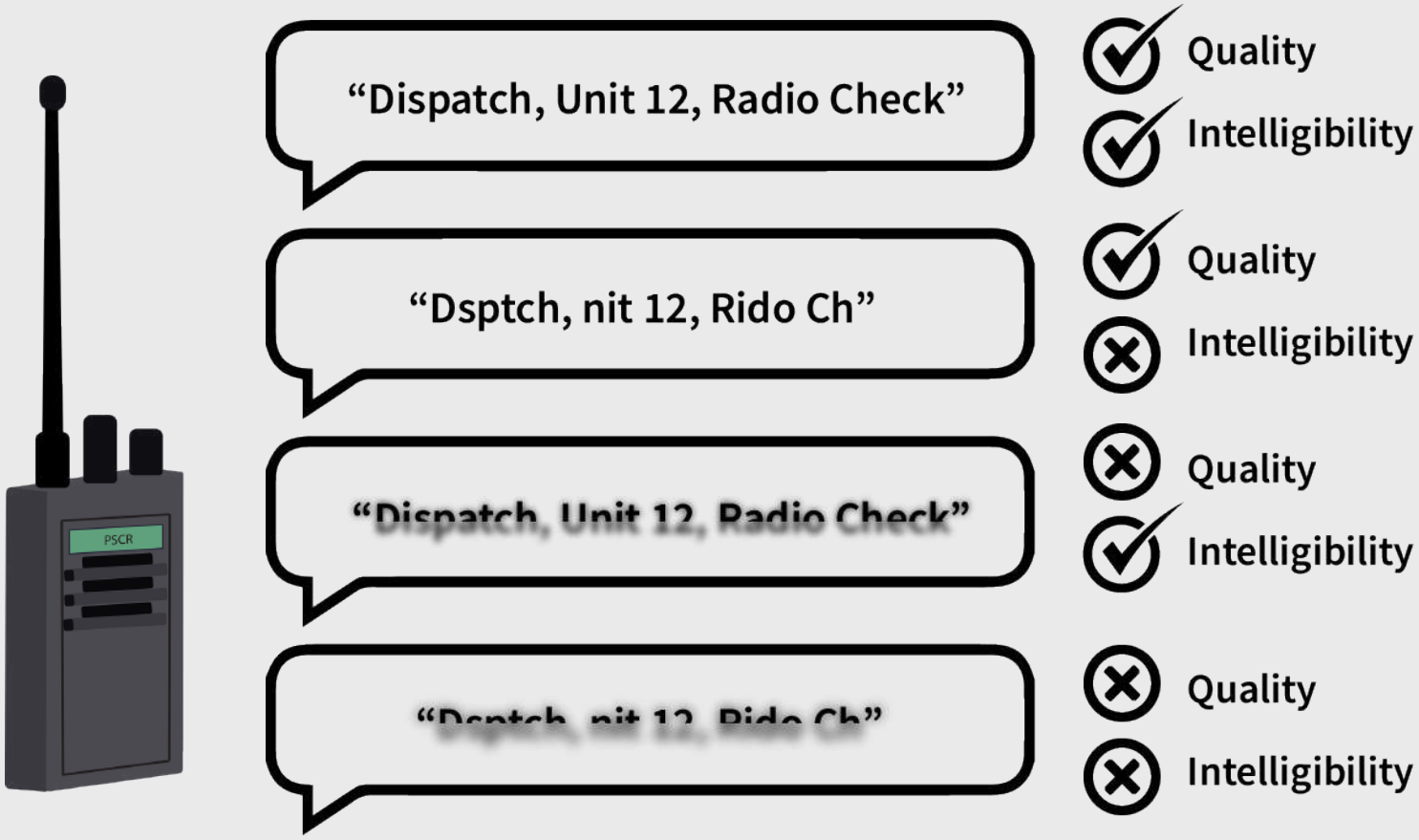
NIST/PSCR Definition of End-to-End Access Time

- Focuses on Access Delay
- Transportable to other Technologies
- More user centric (QoE) measurement than TIA-102 and 3GPP
- Audio in/audio out method
- Audio is started before PTT button is activated
- Access delay is determined by the first speech played back by the receiving device



Voice Quality and Intelligibility

- First Responders Require Intelligible Speech in Challenging Audio Environments
  - Background Noise: Alarms, Sirens, Helicopters, Chainsaws, Gun Shots, Etc.



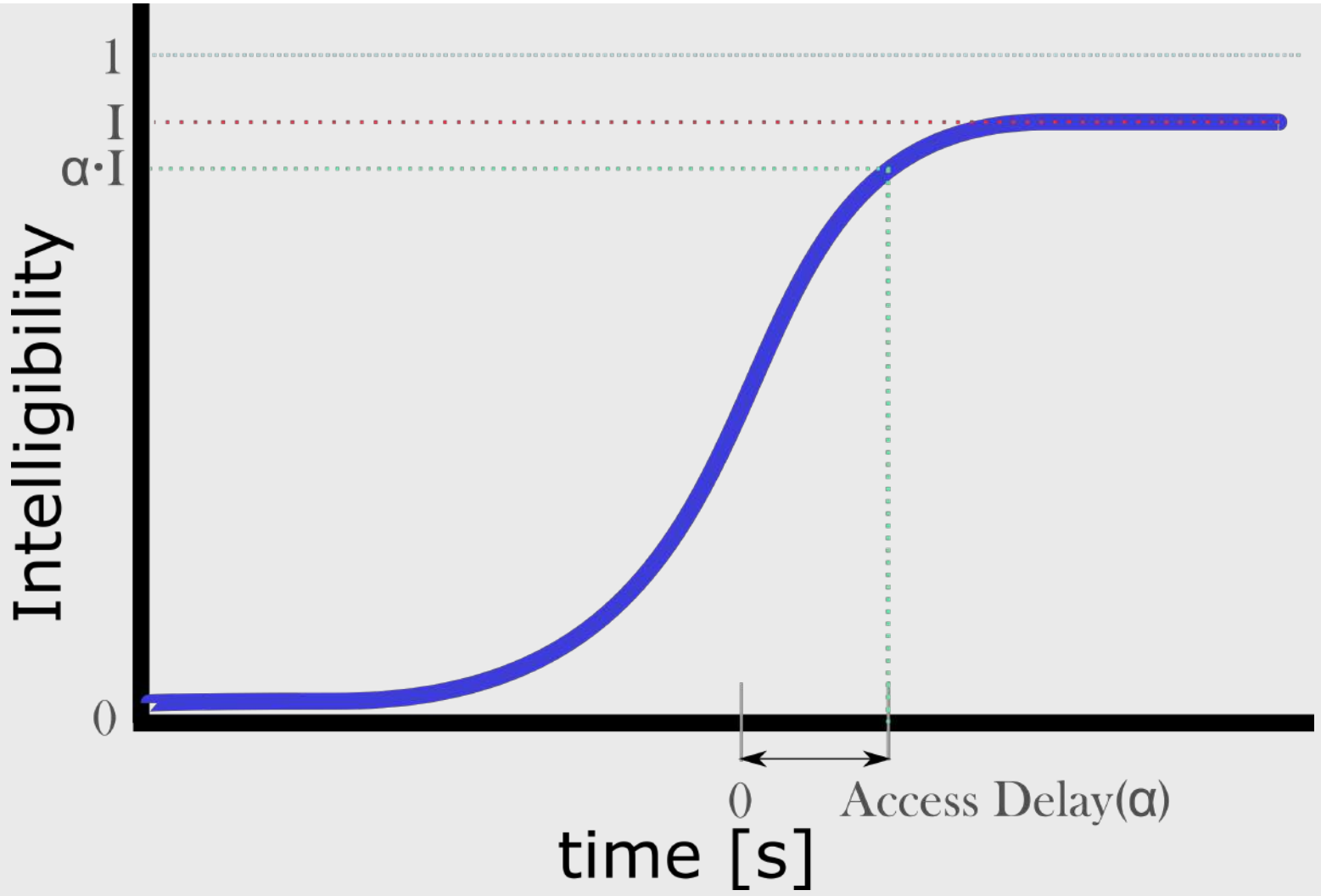
Intelligibility

- Leverage Intelligibility Work Performed by an Audio Expert
  - DJ Atkinson Initiated this Work (Institute for Telecommunication Sciences)
  - Steve Voran (Institute for Telecommunication Sciences)
- Measure Intelligibility using the Modified Rhyme Test (MRT)
  - User Picks Correct Word from Six Words that Rhyme
  - For Example: bed, led, fed, red, wed, and shed
  - Please select the word ----. (Carrier Phrase)
- Requires Extensive Human-Based Testing
- Signal Processing Based Alternative
  - Articulation Band Correlation-MRT (ABC-MRT) and More Recent ABC-MRT16

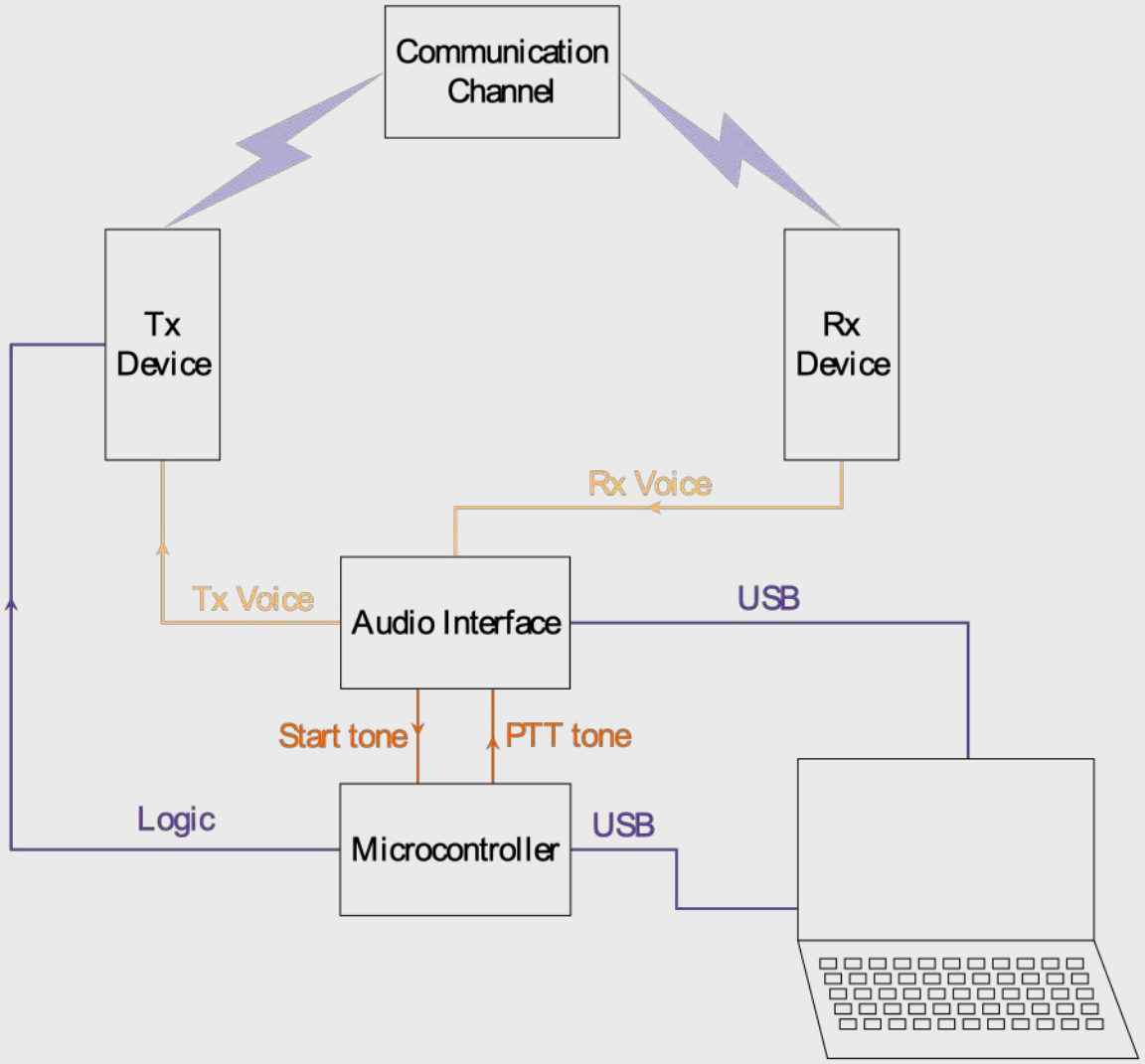
Intelligibility Curve

- Intelligibility is Important to Determine End-to-End Access Time
  - The person on the other end must understand the entire message!
- User Must Wait for Channel Grant (Access Delay) Before Speaking
- Determine Access Delay with a Multitude of Tests
  - Capture Variations in Speech Intelligibility and Variations in the System Under Test
- Vary the Time Between the PTT Request and First Word over a Series of Trials
- Access Delay Measurement Curve for When the System Achieves a Fractional Portion of its Baseline Intelligibility
  - Jaden Pieper's Presentation

Intelligibility Curve



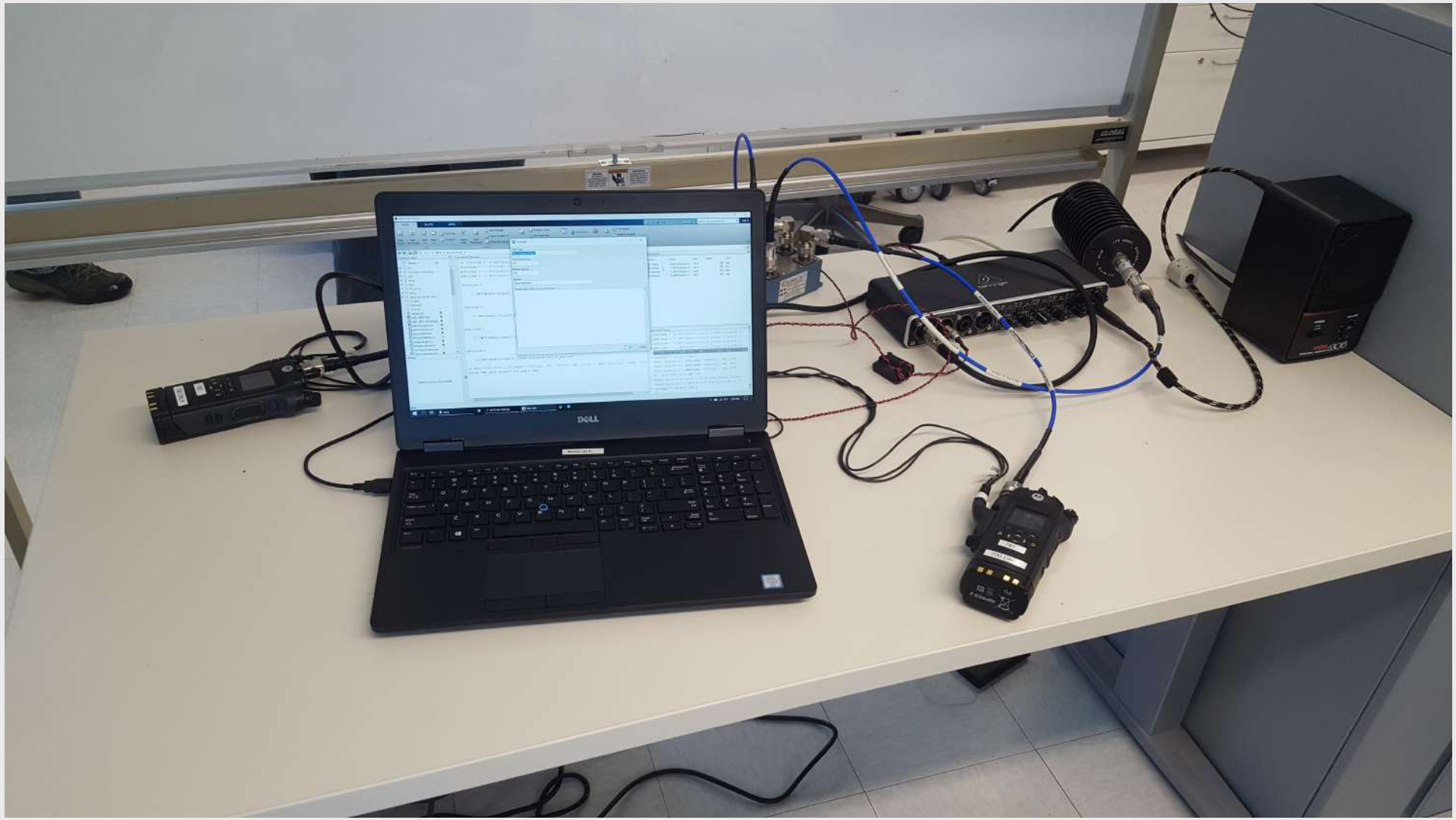
End-to-End Access Time Test Setup Diagram



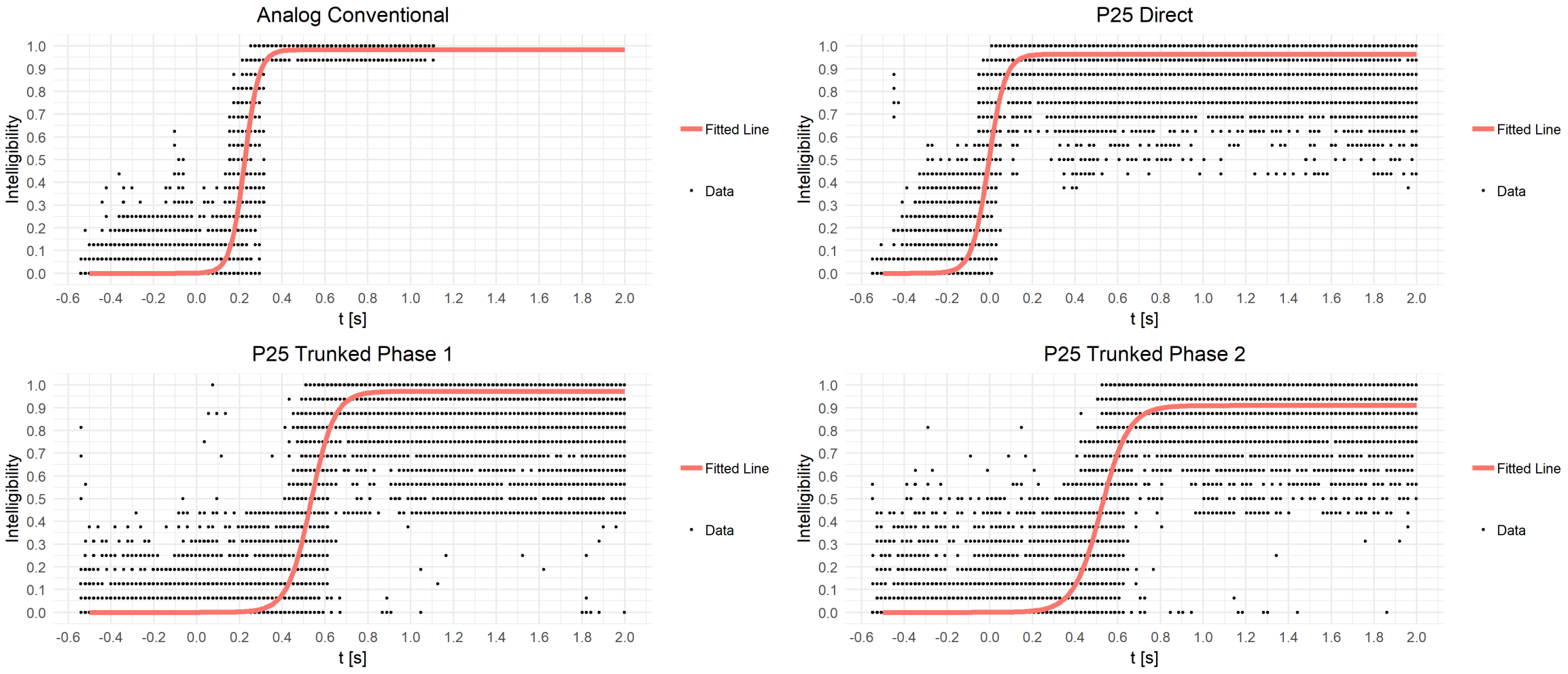
End-to-End Access Time Measurement Devices

- Behringer UMC 204/404HD Audio Interface
- Audio Interface Settings
  - Sampling rate, buffer size, and USB Streaming Mode values chosen to prevent data over/under runs and audio glitches
- Audio Interface Device Characterization
  - Latency: 21.85 ms (± 0.07 ms measurement uncertainty)
    - Time offset between play and record
- MATLAB
  - Audio System Toolbox
    - Used to play and record audio samples
    - Used to automatically key the PTT button via the microcontroller
- R Software
  - Used to quantify end-to-end access time

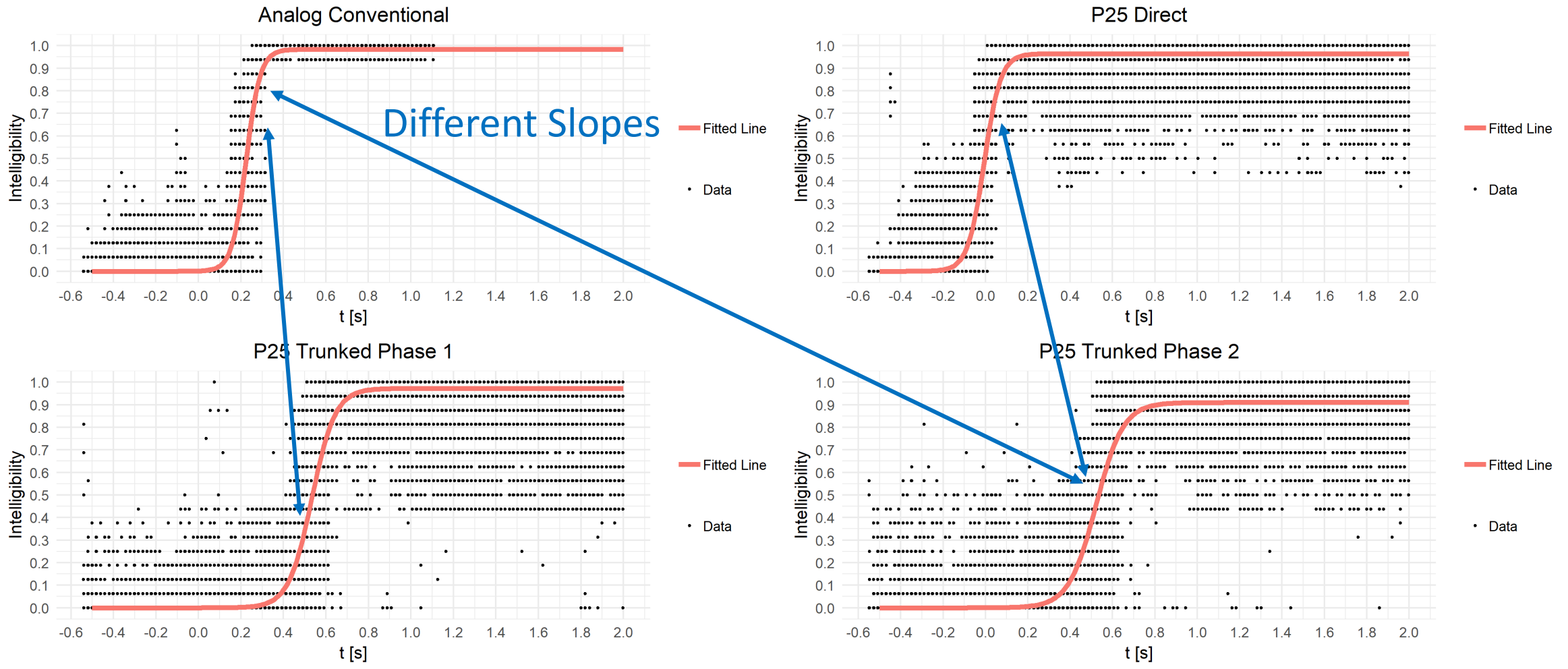
Test Setup (Cabled RF)



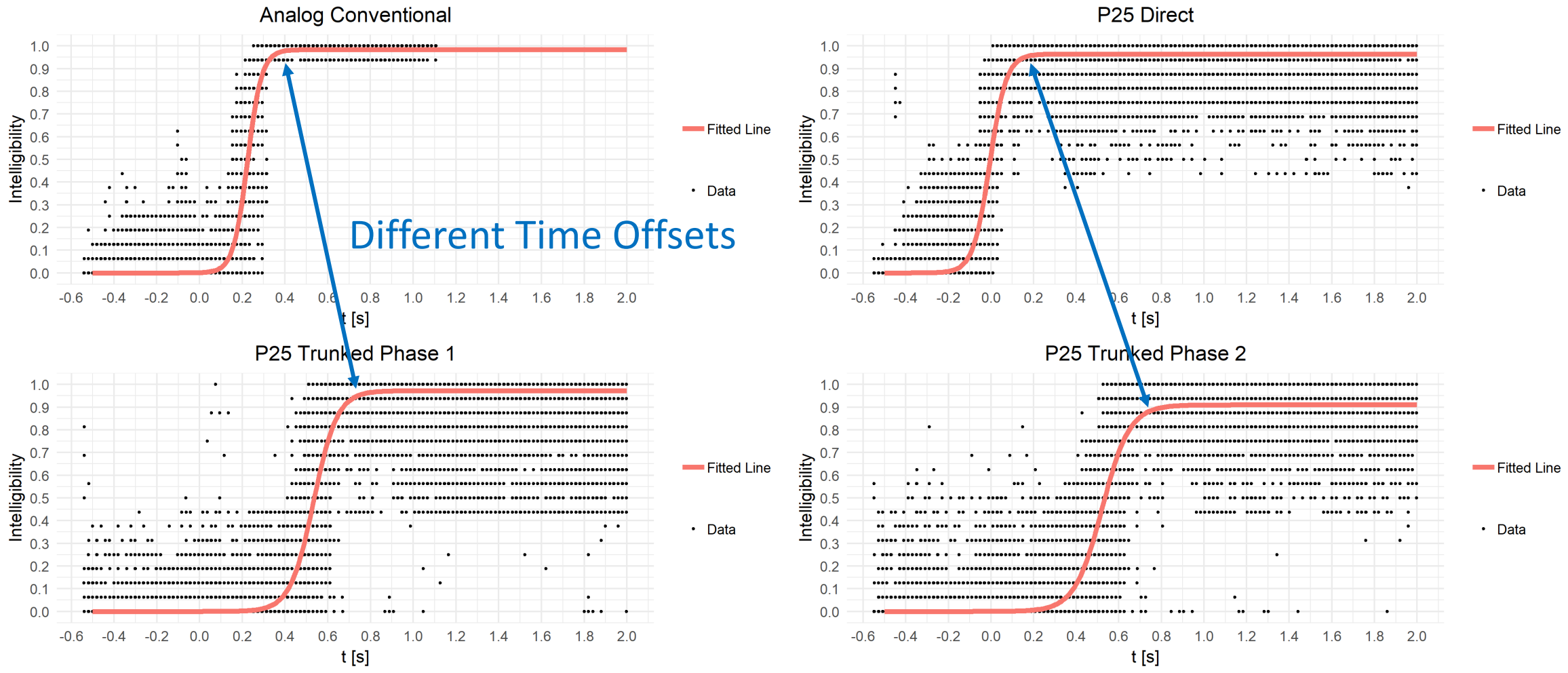
Intelligibility Curves for PTT Technologies



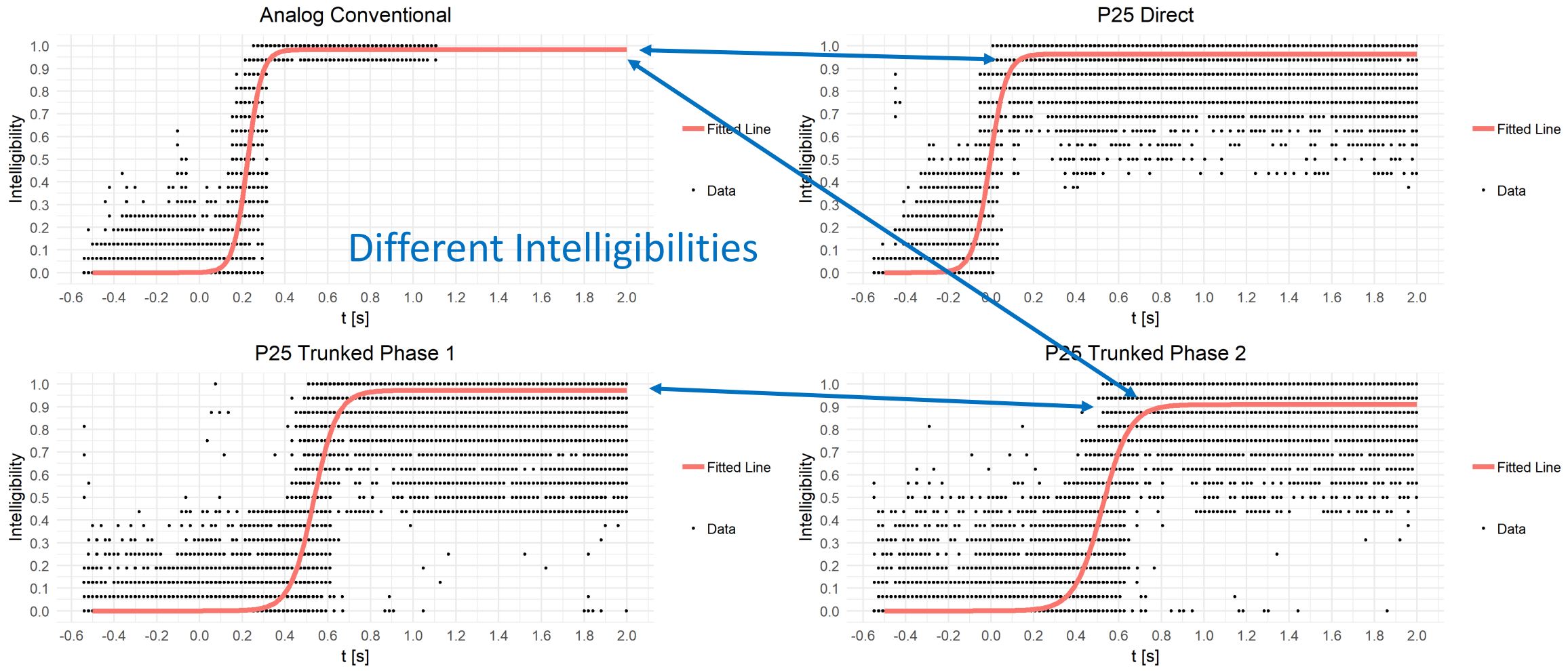
Intelligibility Curves for PTT Technologies



Intelligibility Curves for PTT Technologies



Intelligibility Curves for PTT Technologies



End-to-end Access Time Results for 85% Intelligibility

PTT Technology*	M2E Latency (ms)	Access Delay (ms)	End-to-End Access Time (ms)
Analog Direct	76.5 ± 0.3	136.5 ± 3.3	213.1 ± 3.3
Analog Conventional	78.5 ± 0.3	286.1 ± 2.5	364.7 ± 2.5
P25 Direct	220.9 ± 0.3	71.6 ± 4.1	292.4 ± 4.1
P25 Trunked (Phase 1 – FDMA)	356.6 ± 3.8	640.1 ± 5.1	996.7 ± 6.3
P25 Trunked (Phase 2 – TDMA)	575.9 ± 8.1	692.2 ± 7.1	1268.1 ± 10.7

*Analog Conventional operates in VHF band.
All P25 technologies operating in 700 MHz band.

Future Work/Direction

- End-to-End Access Time Measurement Method
  - Requires Further Development
    - Jaden Pieper to Lead with Assistance from the PSCR MCV Team
  - Validate Measurement Method on MCV Systems in the PSCR Lab
    - PTT over LTE
    - FirstNet LTE
    - DHS Interworking Capability
    - Field testing
    - LMR-LTE Interconnected Systems (Long-term Goal)
    - Tim Thompson to Lead with Assistance from the PSCR MCV Team
- Audio Quality/Intelligibility
- Access/Retention Probability

For More Information

- Demo of End-to-End Access Time
  - Today at 4:20-5:30pm
  - Michigan Ballroom
- Poster and This Presentation is on the Mobile App
- Jaden Pieper's More Technical Presentation
  - MCV QoE Speech-Based Access Time Measurements
  - Great Lakes DE on Thursday at 1:50-2:35PM
- End-to-End Access Time Measurement Method
  - Paper, Test Results, and Code Available on the PSCR Website

Team Members

- Back Row
  - Steve Voran
  - Tim Thompson
  - Jesse Frey
  - Zainab Soetan
- Front Row
  - Hossein Zarrini
  - Don Bradshaw
  - Chelsea Greene
  - Jaden Pieper


NIST
PSCR
THANK YOU

#PSCR2019

Get your hands on the tech!

Demos Open

BACK TOMORROW

8:00 AM

Executive Summary

Mission Critical Voice QoE Measurement Methods

- Backup Slides

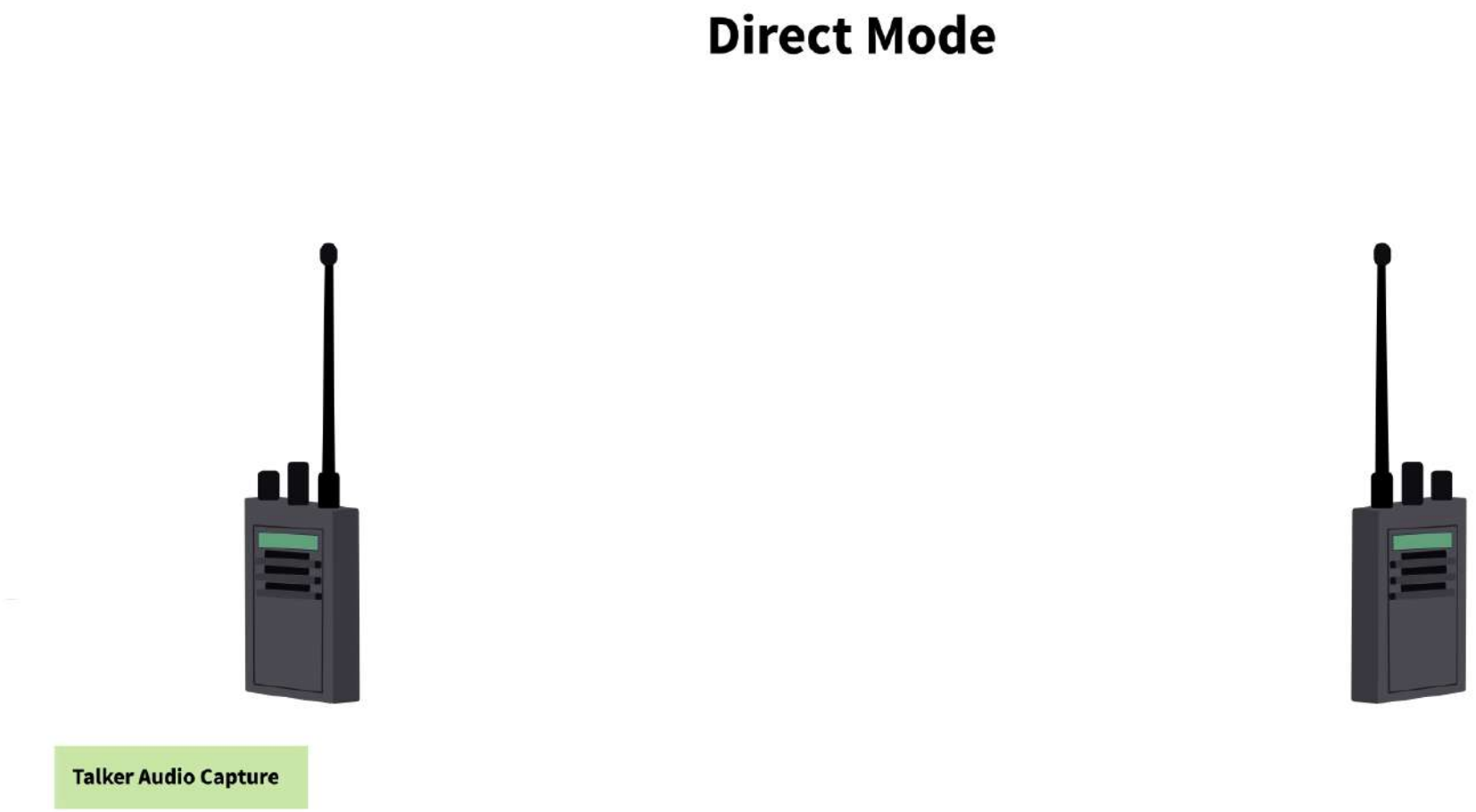
Mission Critical Voice QoE Measurement Methods

Access Delay vs. Intelligibility

PTT Technology	90% Intelligibility (ms)	80% Intelligibility (ms)	70% Intelligibility (ms)
Analog Direct	149 ± 4	120 ± 3	101 ± 3
Analog Conventional	298 ± 3	271 ± 2	253 ± 2
P25 Direct	62 ± 4	35 ± 3	17 ± 2
P25 Trunked (Phase 1 – FDMA)	575 ± 5	539 ± 4	515 ± 3
P25 Trunked (Phase 2 – TDMA)	TBD ± ?	TBD ± ?	TBD ± ?

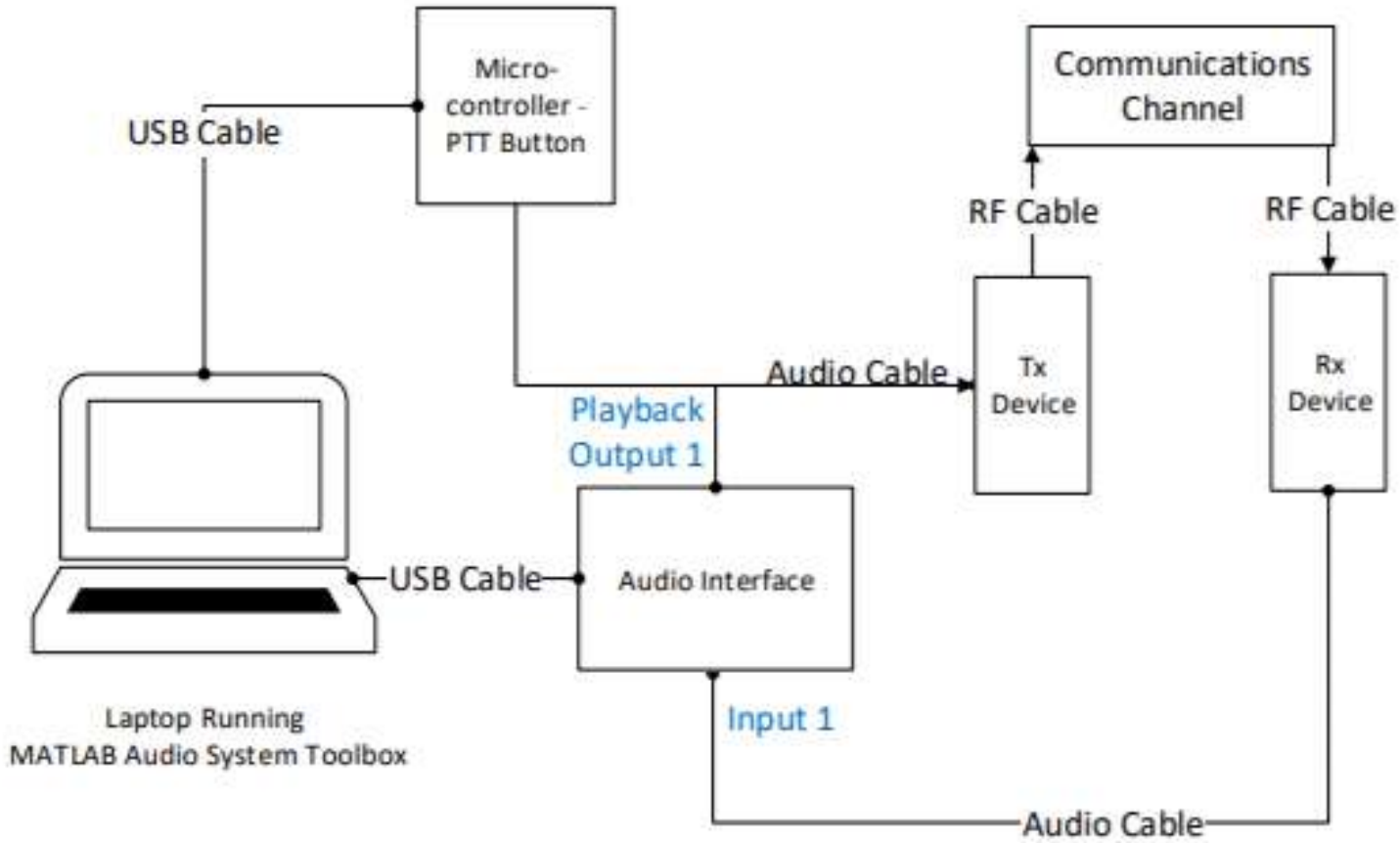
Mission Critical Voice QoE Measurement Methods

M2E Latency – Direct Mode



Mission Critical Voice QoE Measurement Methods

One Location Test Setup Diagram



Site 1 – TX/RX

Mission Critical Voice QoE Measurement Methods

UHF Direct Mode One Location Setup (Over the Air)